Climate Change Science and Management Webinar Series
USGS National Climate Change and Wildlife Science Center
FWS National Conservation Training Center

AK CSC Ecodrought Webinar: Assessing Soil Moisture Availability across the Gulf of Alaska Region

Speaker(s):
David D'Amore, USDA Forest Service, Pacific Northwest Research Station

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John Ossanna: How's everybody doing today?

I'd like to welcome everybody to the USGS and NCCWSC Climate Change Webinar series where it's hosted here through the National Conservation Center, through the U.S. Fish and Wildlife Service.

Today we have a presentation from David D'Amore. He will be discussing assessing soil moisture availability across the Gulf of Alaska region.

At this point, I will hand it off to Abigail, who will introduce our speaker.

Abigail Lynch: Thanks. Hi, this is Abigail Lynch. I'm a research fish biologist with the National Climate Change and Wildlife Science Center.

It's my pleasure to introduce today's speaker, Dave D'Amore, who is a research soil scientist with the Pacific Northwest Research Station of the USDA Forest Service in Juneau, Alaska. He received his PhD in Natural Resources and Sustainability from the University of Alaska Fairbanks in 2011.

He started his career in natural resources as a forester with the Peace Corps in Mali, West Africa, where he did reforestation and soil conservation projects. D'Amore also works in forests of the Pacific Northwest as a soil scientist and forester.

He has worked in Southeast Alaska for the past 20 years on soils and forestry products related to nutrient cycling. His recent research work has examined the interaction between terrestrial and aquatic ecosystems with a focus on restoration and carbon cycling. Welcome, Dave.

David D'Amore: Thanks very much. Glad everyone could join us today to talk about this project. I'm very excited about this modeling work that we've been able to do in the region. I'm looking forward to highlighting some soil moisture topics across the Gulf of Alaska region.

First of all, I'd like to acknowledge my co-authors and collaborators on this project, Frances Biles, Julian Schroder, Tom Kurkowski, and Scott Rupp. Frances and I are both employees of the U.S. Forest Service. Julian, Tom, and Scott work at the University of Alaska Fairbanks, actually, the Scenarios Network for Arctic and Alaska Planning.

This project was a three-way project with the University of Alaska Fairbanks, the Forest Service, and the Department of Interior's USGS Climate Science Center, Alaska Climate Science Center, which funded this proposal jointly. I'd like to acknowledge that. I really appreciate the support.

A good example of how we're trying to come together to address questions like this across a very vast region in Alaska and the coastal fringe.

Just to start off to put us in perspective, we are working in what is known as the Gulf of Alaska region, which is this northeast pacific coastal margin of the coastal terrestrial fringe that runs around the Gulf, starting at southern British Columbia, and extending up off into the Aleutian Islands. A tremendously important area in terms of fisheries production, forestry sources and fresh water.

This region actually has a few large rivers, but not any one major river, which drains the region. We experience two to five meters of rainfall throughout the region, which culminates in an integrated discharge of about 800 cubic kilometers of water coming off the land into the Gulf.

That's about four times the discharge of the Yukon River and it's actually greater in cumulative discharge than the Mississippi River. A huge amount of fresh water. We're concerned about that water and its transit time across the soils of the region.

Specifically, today, we're going to be focused on a sub-section of this region, which we call the southeast Alaska drainage basin. That's our area of interest in the trans-boundary rivers and the extended island archipelago, southeast Alaska, where the modeling was done.

This map also shows the extended coastal temperate rain forest region, which actually has four sub-regions extending from south-central Alaska all the way down to northern California. We have a broader research workgroup working on these broader regions, but today we're focusing on soil moisture relationships in the Alaska drainage basin.

The landscape is a tremendous mix of vegetation and the evolution of this landscape actually is mostly driven by water. As you can see here, we have forests, but they're interspersed often with open heath and bog vegetation. Mixes of the culmination of vegetation and, we'll talk about that a little later, but really a combination of waters leading to varying vegetation communities.

This is a model that we use in soil science. I am a soil scientist. We use a model called the Catena model. It really works well here because it illustrates how topography really influences the development of vegetation associated soils.

This is a really applicable model in this region because topography is destiny here. If you can drain water, you end up with much deeper well-developed soils, mineral soils. If water isn't transited away from the system, you end up with peat ones.

At the bottom, there, those are *Dysic Typic Cryohemists*, in soil language, actually can be up to four or five feet meters deep of organic matter, organic peat, and hold water really closely and pool it on the surface.

Again, really distinctive soil types and different processing of water. One of the challenges is trying to understand how this water is distributed on the landscape, what its resonance time is, and several questions related to what that water's doing in terms of its feedback in, not only the vegetation, the biogeochemistry, and really assessing how that's going to change.

I'm going to outline some of the things that we've done in that arena. The other constraint we have is that we don't have maps of soil moisture, which transcends the whole landscape in the region.

Our challenge was to actually come up with a model where we had a readily accepted approach to model soil moisture as an index across the area. As I said, water is driven primarily by topography.

Our key task, the first key task, was actually combining all of the digital elevation models into a seamless array to use across the region. This actually was a really challenging task because of different data sets, different resolutions, and an incredibly complex and diverse topography.

This outlines some of the steps we used to bring that digital elevation model together, which drives a lot of water flow models across the region. Here is a composite of the input data sets.

What I'll show next is actually...This moves and goes into Canada. That large black line is the outline of the drainage basin which is, again, there's no border in here, so no international border. These data sets actually, we're combining Canadian data from British Columbia, and the Yukon along the southeast Alaska, and the USGS data, into one seamless data set.

In terms of products, we now have a digital elevation model, which is unified across this region, which allows us to do, not only soil moisture modeling but other things, as well. This was a huge advance in our combination of data sets throughout the region. This wasn't without its challenges. This illustration highlights one of the interesting things.

Funny things happen when you cross the border. The two circles highlight an area of the US-Canadian border. The top circle, if you see, there's a thin outline that looks like kind of a line there.

Well, that's actually where the DEMs came together and did not match up. A huge challenge was to try to get those matched up in a way where water would flow. That's actually a scarp, a cliff, where imagine it's like a waterfall or a dam for water going one way or another.

The bottom circle shows how we overcame that using a program produced by Dan Miller of TerrainWorks, where you can merge data sets and create a seamless layer to overcome those areas where we had those blockages. Once we had the digital elevation model, we were able to move on then into creating a topographic wetness index.

Now, a topographic wetness index is a fairly straightforward exercise, in most cases, where a simple equation -- you can see it down there in the middle of the description of our assumptions, TWI -- a simple equation that actually combines a local up-float contributing area, the local up-float contributing area, along with slope, in an equation.

Now, the problem with that is there are a lot of assumptions that go into that. Part of the task and the major part of our task was actually developing good assumptions to build into this so that we could seamlessly apply this index across the region.

Essentially, we're able to do that, and unify this area into a DEM-derived topographic wetness index, which becomes a base layer and sort of a version 1.0, as a seamless soil moisture map. Now, remember this is just an index of the water from wet to dry. If you see that in the legend, a high topographic wetness index, meaning wet areas, and low topographic wetness indicators, indicating dry areas.

Again, it's just a first approximation of the area but it lends itself to broad-scale regional modeling and monitoring for moisture flow and accumulation of water. This layer is available. The website is noted at the bottom of the slide here.

Again, it's a tool. It can be used in a lot of different applications. The other thing is it can also be altered. Again, it's all available in code, so that it can be altered and adjusted for local conditions, for different uses.

Again, we wanted it to be a dynamic tool. But the goal was to apply something across this broad complex region that would be a standard that researchers and managers could use in various applications.

Simply enough, this tool exists. It provides a base layer for soil moisture across the region. Now, what I want to do is highlight some of the things that it can be used for. Now, where we're progressing with this tool to tailor it to some key questions that we have about resources and water in the region.

One of the nice things is this lends itself to applications that...the index is actually a non-specific index but doesn't have any...the values are not related to anything tangible. The first step, what we can do is actually relate it to a continuous variable by modeling the index compared to known depths to water table.

The depth to water table becomes a specific continuous variable that we can then have something meaningful for what we use in planning and modeling. The example here is a sigmoidal curve that can be set, that transcends the wet region. You see the high values there along the X-axis, which is actually at the top of the figure and the dry values to the left, as you go down.

If you notice, there's not a lot of change in the wet areas, out to the right. Then the dry area becomes very, very apparent. In between, there's a place in that index actually where there's a lot of variability.

That's actually in the transition between those wet to dry areas, which we see in a lot of our work here. There is a lot of difficulty in evaluating those in-between areas which are wet and dry. Again, we have a huge amount of moisture, so that change is very subtle on the landscape, hard to model.

Again, here we have the map, again, of the Alaska drainage basin arrayed as a continuous variable, now, of model depth to water, which could be used to test project areas, as well as, follow water table depth through time.

Again, let me go back and try to paint a picture of a specific application, which is valuable to us in landscape modeling. Back to the Catena idea, we know that there's a distinct association of above ground vegetation responding to the below ground condition, specifically soils.

Our soil maps are at a very coarse resolution. This slide illustrates the soil map units. A soil map unit is just a modeled collection of soil units, in the field, that have been described in the field but are modeled as a map.

Now, if you look at the numbers such as 36KC, 61T, 44JD, those are called soil map units. Those map units are not a distinct individual soil. They're actually what are called complexes. Those complexes of soils have two major soil types. Often, those two major soils types are very different.

The example we're using here, if we focus in the top portion of this figure, 36KC, is actually a wet soil and a dry soil combined into one map unit. The topographic wetness index are the colors underneath that and you can see the stream channel, the main channel of this watershed, running through the middle of that map unit.

You can see how much more resolution is provided by the topographic wetness index and within that map unit and the variability unit. What this does, and in the next slide, we'll show you the progression.

Now, 36KC, that soil map unit is now identified on the left with the pink outline with the continuous topographic wetness index within the unit. Again, you see the variability. One thing we can do in terms of applications of soils is what we call disaggregate that soil complex into its two component parts by soil moisture.

On the right, what you see is 36KC now sub-divided or disaggregated into two distinct soil types. This is a much more powerful approach to understanding much higher resolution response in the landscape to water. One of the uses here is that we can look at areas that might be vulnerable to soil moisture change as opposed to others.

One thing we're concerned about, this figure from Charney's recent paper in Ecological Research Letters, shows the projector modeled forest growth change. This growth change is associated not only with drought but insect and disease.

If you notice, there's a tremendous variability across North America. The big concern with forest, especially, is what's the trajectory of change given changes in temperature and moisture relationships? How do we model this? How will we know? Well, the first place to look is how that groundwater, the source of the transpiration water for trees is going to change.

An interesting thing in southeast Alaska, I described how wet it is and how much rainfall we get. But, an intriguing part of our climate, actually, is that we do experience a drought period or where evapotranspiration exceeds precipitation during the spring and early summer months. This graph shows that sort of soil moisture deficit in the June-July period or at least close to it.

Again, this is something we've been watching for a few years and wondering about how this area might change. How does this period of time, which is the beginning of the growing season, might actually change and affect plants and soil moisture in the region?

These two figures are a couple of figures from my colleagues at the Scenarios Network for Arctic and Alaska planning, where they show projected temperature and precipitation changes.

Temperature change is on the left. It's pretty clear with a high degree of certainty that we will be experiencing increased temperatures into the future in southeast Alaska.

These figures are for Juneau, the capital of Alaska, in the center of southeast Alaska. On the right, is precipitation. Precipitation is a lot more uncertain. Recent models are showing that the increases that we might see in precipitation may actually be due to larger winter storms.

Again, it's unclear if that increase of precipitation is going to occur during that, what I just showed, that drought period. What we do know is that we'll probably be experiencing more higher temperatures, which would lead to higher evapotransfer of loss out of the soils. The potential for more moisture demand from the soils which are not being recharged by precipitation.

This figure shows some actual water table modeling we've done. The actual data is shown on the black-dotted and black dashed lines for a couple of different ecosystem types, our wet ecosystem types. What that shows is some variability across the months in that draw-down period. The red line is the potential increase draw-down with this evapotranspiration loss and not recharge.

This figure shows it a little more clearly, just taking out some of the differences. It shows it across June. What you can see there is, just focusing on the middle dashed line, for our forested wetland sites, you can see that the zero represents the soil surface.

The negative numbers represent the depth to that water table below the surface. If you look at about 06/19/2006 there, you can see that there's about 20 centimeters of aerobic zone in the surface of this soil.

With increased water demand and drainage, that surface could decrease further. The red is just an illustration of what could happen if we just had a step-wide decrease in that soil moisture. What that does is that increases the aerobic area and the potential aerobic decomposition of that organic matter, just to illustrate what may happen.

What we can do with the topographic wetness index and the fixed water table depth is start monitoring this and start tracking these changes over time and apply them to the broader landscape, so just an idea of that application. Another application that we've used this model for is in the widespread, current Yellow Cedar decline. Yellow Cedar is declining due to a reduced snowpack and fine root freezing.

We see this extending over both southeast Alaska and British Colombia, extensive areas of the Yellow Cedar range. Yellow Cedar is prone and is much more competitive in wetter zones of a landscape. We know that its propensity is to occur on wetter portions of the landscape and is susceptible to this snow-related injury. What we're able to do is combine both the TWI with a snow model.

What this graph illustrates is the landscape drape of the range of varying topographic wetness indexes, the dark blue being wetter, and the light blue being drier, along with that bright yellow line, is the spring occurrence of snow, where snow persists in the spring.

The root freezing tends to occur more in the spring because we get thaw-freezes, where we get thaws followed by cold snaps, which kill the fine roots. The red you see on this is the actual map extent of the decline across the landscape. You can see the association with the snow.

Using this model, we're able to combine the model precipitation as snow along with the topographic wetness index to come up with a cedar suitability index or a risk assessment of going into the future where areas of higher risk for Yellow-Cedar decline would occur.

This is a management tool so managers can look at an area and have some type of idea about where zones of risk might be related to this loss of snowpack. Now, we had to make some compromises in this model because there were good models available for modeling precipitation as snow into the future, but we couldn't yet make the soil moisture move.

As I illustrated in the past slides, that's just a theoretical reduction in soil moisture. We aren't sure. We need to do some more research work on that. We do have this universal, regional moisture index to use as a baseline and move into the future in terms of modeling, how soil moisture might change to adjust this model.

One last example. A large part of our research is looking at the carbon flux from this landscape.

A key part of that carbon flux is that it is very different in terms of the gaseous versus dissolved components as you move from these heavily forested, well-drained areas to these open, illustrated here in the middle of this picture, are muskeg areas or poor fen bog areas, which are treeless, which become much more saturated and subject to the excursions of dissolved organic carbon as organic acids.

At present, we are using what we call hydropedologic units, so we can use, again, going back to the soil map unit, these aggregations of ecosystem types that are mapped on the landscape as polygons. You can imagine, as a vector-type approach, where we look at just units. At the moment, we use three major units because they represent three major flux components on the landscape.

One of the things we're really worried about, in the left area, you see the high concentration of the organic acids brewing out of the wetlands in the system. Again, those organic acids make a very short excursion through the freshwater system to the nearshore marine.

That's one of our major components, which comes out of our wet areas. If we had a better idea of where those wet areas are on the landscape, we could start making more continuous maps for the excursion of this component to the nearshore.

Essentially, we can measure the excursion of those dissolved organic acids coming out of the landscape. We've been able to map it across the region of the southeast Alaska drainage basin. As you see here, we've arrayed them into what we call carbon sheds or the characteristic loss of carbon as dissolved organic acids to the nearshore marine.

This is a really key component of some of the dynamics of the biogeochemistry of the region. Again, this is primarily driven by that huge amount of precipitation, the quick transmission of that precipitation as freshwater discharge. That freshwater discharge is mediated by this flow through the soils. It also picks up these materials, such as organic acids, on its way to the nearshore coastal.

Just to illustrate, here's a photo of chlorophyll-a concentrations from a NASA satellite of this region. You can see, clearly, the connection between the land and the Gulf of Alaska.

Once you see those spirals that you see going out into the Gulf of Alaska -- they are called Sitka and Haida eddies -- which are carrying this freshwater discharge, along with the nutrients entrained from its interaction with the terrestrial environment, out into the Gulf.

These are seen and hypothesized as really important components of the North Pacific Coastal productivity, which is a big part of some of the things we're testing, throughout our present and future research in the region.

This brings together this idea of why soil moisture, why do we need to understand it, what are some of the key things that are happening, and what are the real key needs to track as we get these atmospheric and climate changes that are being this oppressed type disturbance on our region overall?

Well, this tool that we've developed is one way that we can start understanding that change across the broad region and having at least a baseline metric that we can use and share with colleagues to start examining some of these questions. That's about it for the presentation. John, I'm not sure how to open it up for questions now.

John: We have a real quick question from Ulysses. What equipment is being used to measure soil moisture in the field?

David: Yeah, that's a really good question. Thanks. We've struggled with some of the traditional measures of soil moisture here. There's two ways to measure two major soil moisture components in soils. The first is gravimetric moisture, where water is just controlled by the gravity and results in a characteristic water table, where you have water not under tension at all, so zero tension.

We measure that simply with, we use the traditional way is PVC pipes, which are slotted to allow that water to flow freely from the soil into the pipes. Then you can use a hand measurement or currently, we use pressure transducers, which is a sensor, which goes into the tube and measures the amount of water over the sensor. It gives you a direct measure of the level of the water over the sensor.

The other way to measure moisture is water that's held at tension. That's water that is under a pressure or tension in the pores of the soil. There are several methods that are available for doing that, such as time-domain reflectometry. There's also small electrical sensors.

What's really difficult, the type of soils we have here have such high-tension moisture or water near saturation and we have such coarse materials, large pores holding lots of moisture, that we don't get really good connectivity in our soil, especially organic soil.

It's been very difficult to get accurate tension measurements. So, we use depth to characteristic water table, the permanent water table. The figures I showed were actual measurements of water depth to water table, in most of those.

That's a really good question and it's actually important. A lot of the measurements you're seeing now, especially like the NASA's Soil Moisture Active Passive mission, and things like that, are measuring, generally, water held under tension in the soil or the amount of water there.

In other regions, that's really important because that is what controls the drought stress, or what we call in soil, the permanent wilting point, where plants can no longer extract water from the soil. But, up here, we're so wet that we tend to measure just that gravimetric water content.

John: Are there any other questions out there for David? Thank you very much, David. I'd like to also thank our partners at USGS and NCCWSC for allowing us to continue this webinar series and look for more of them in the future.

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